SIMPSON GUMPERTZ & HEGER

Engineering of Structures and Building Enclosures

Considerations in the Repair and Replacement of Historic Windows

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California Preservation Foundation Webinar

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Engineering of Structures
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Learning Objectives

- Learn criteria used in specification of new and repaired windows and understand their significance
- Know the methods for water testing existing windows
- Understand how to improve the air and water resistance of historic windows
- Find out lessons learned from a recent steel window rehabilitation project

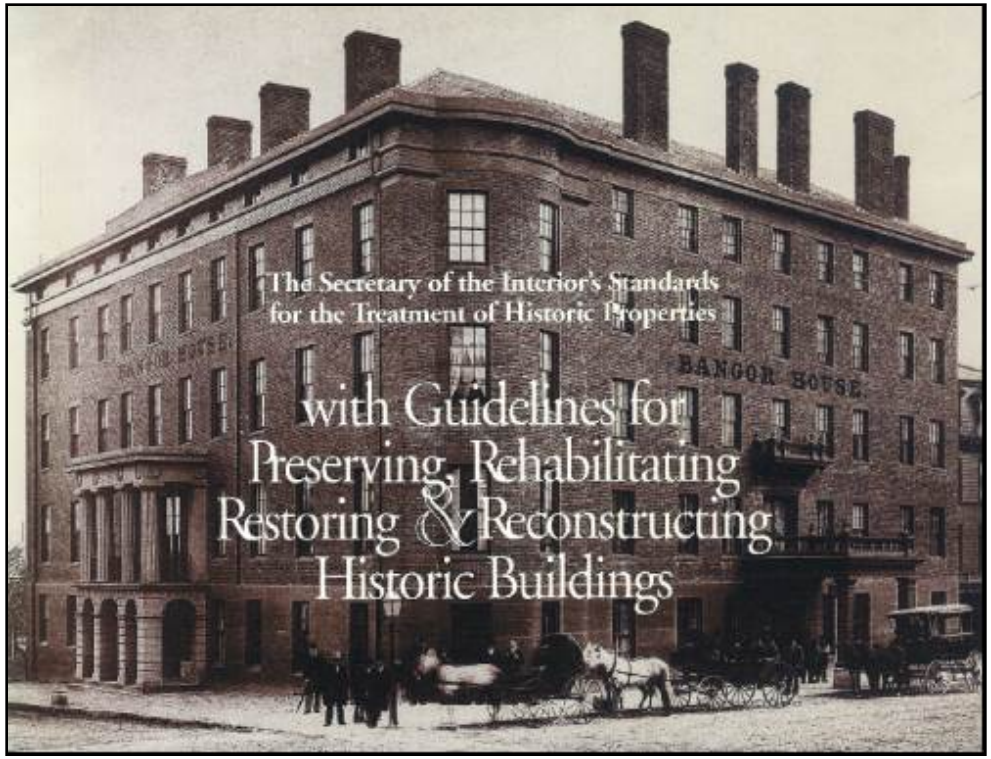
Historic Preservation Considerations
Significance of Windows

- Determine building's eligibility for Local, State and National historic registers
  - City or jurisdiction requirements
- Buildings must possess "historic character" and "integrity"
  - Do the windows contribute? Are they a character defining feature?



Historic Preservation Considerations
Preservation Guidelines

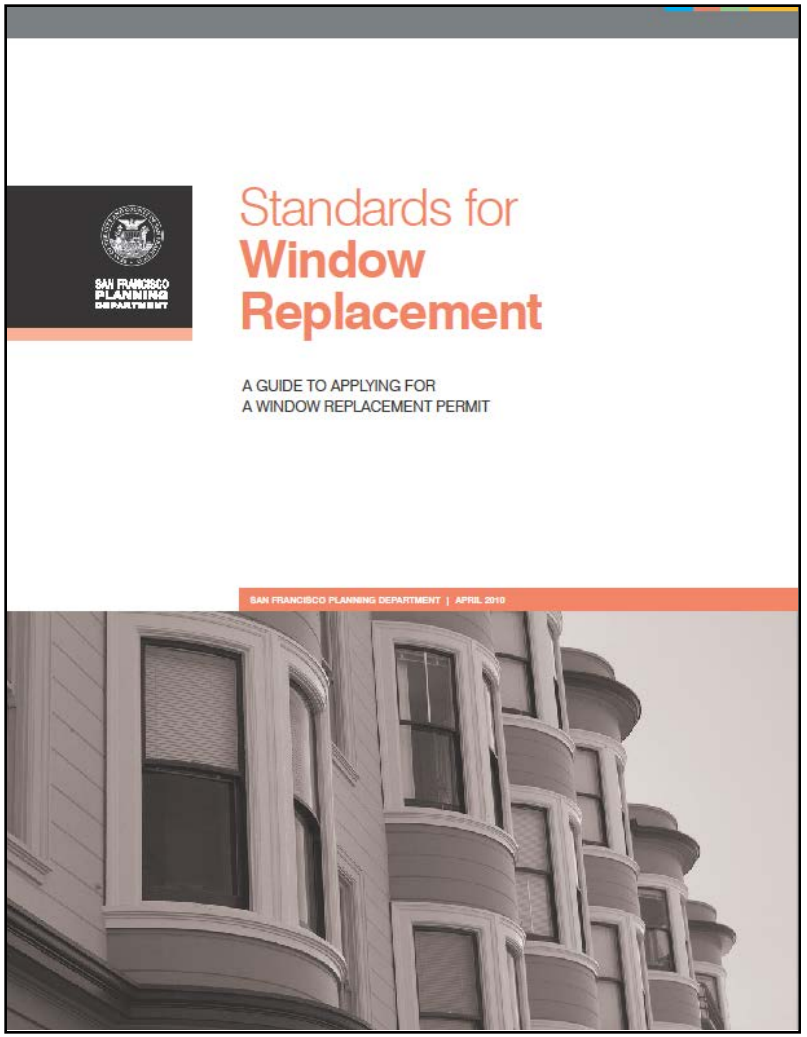
- Secretary of the Interior's Standards
  - Guideline for work on all buildings listed in the National Register of Historic Places and many other registers
  - Four standards: Preservation, Rehabilitation, Restoration, Reconstruction



Historic Preservation Considerations
Preservation Guidelines

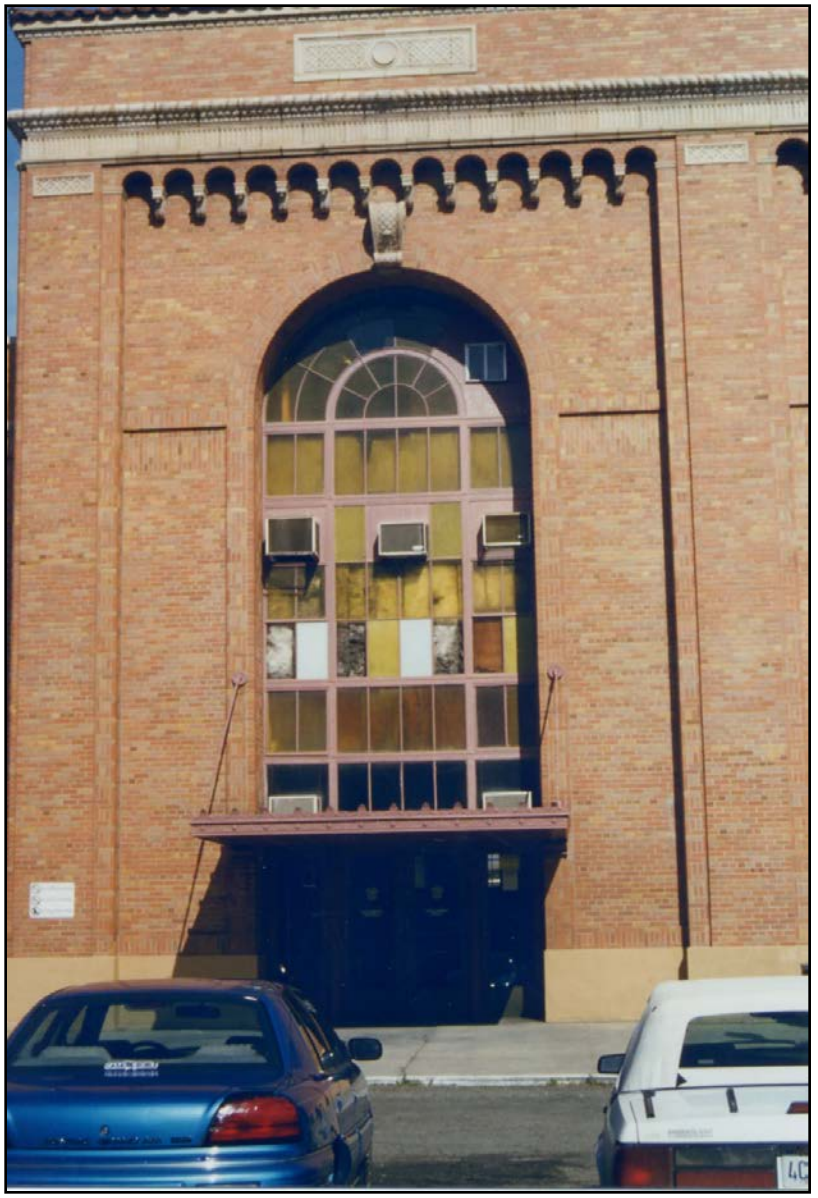
- Local standards and guidelines: San Francisco
  - Retain not replace
  - Replace in kind where visible from street
  - No simulated divided lites
  - How to apply for a window replacement permit

- Other cities: comply with Secretary's Standards



Secretary's Standards for Rehabilitation

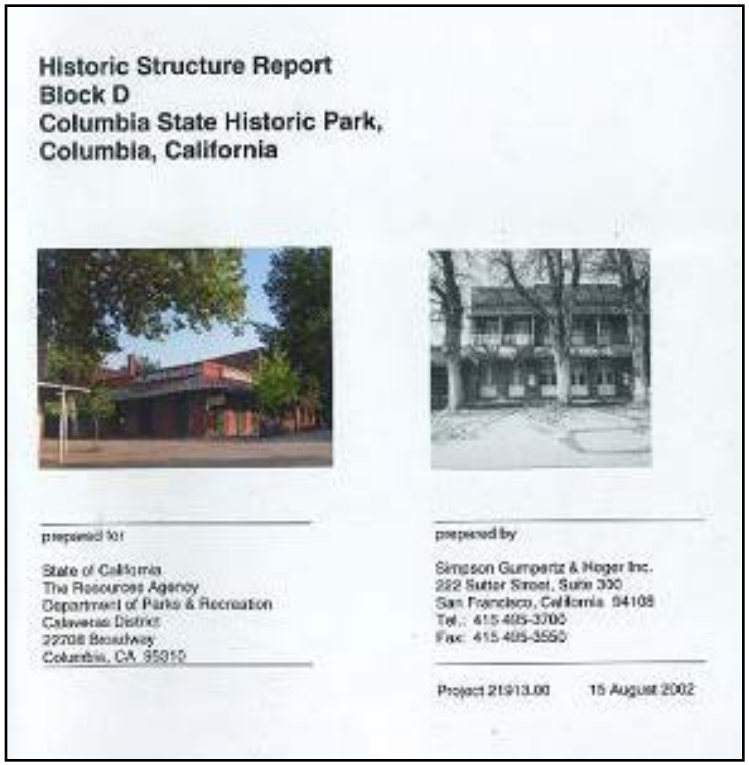
- Allows for the repair and replacement of deteriorated features while maintaining the historic appearance
  - Repair deteriorated features rather than replace
  - If must replace, use original materials
- Allows for new uses that require minimal changes to distinctive materials, features and spaces
- Allows for compatible additions that do not destroy the character of the building and can be removed in the future.



Systematic Approach to Investigating Windows

- ASTM E 2128 – Standard Guide for Evaluating Water Leakage of Building Walls
  - Document review: barrier or drainage system?
  - Interviews: leaks?
  - Window condition survey and investigation openings
  - Air and water infiltration testing
- Preservation Brief 7 – The Repair of Historic Wooden Windows
- Preservation Brief 13 – The Repair and Thermal Upgrading of Steel Windows

Systematic Approach to Investigation


Historic Structure Report
Block D
Columbia State Historic Park,
Columbia, California

prepared for

State of California
The Resources Agency
Department of Parks & Recreation
Calaveras District
22708 Broadway
Columbia, CA 95310

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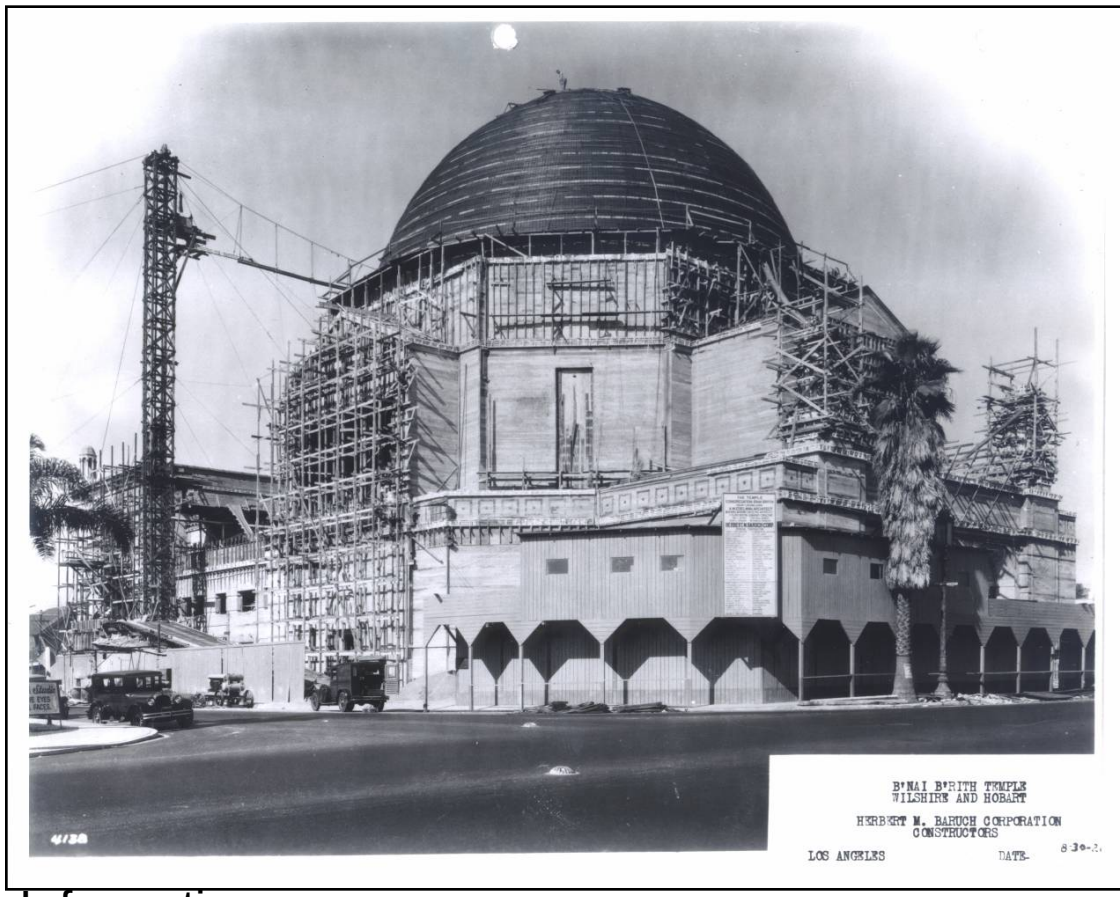
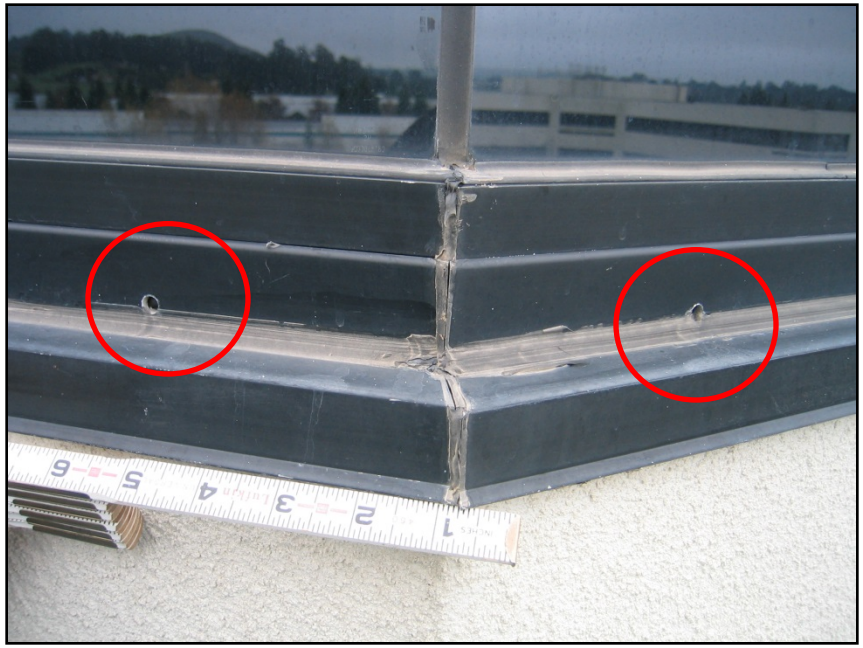


Information Sources

- Historic photographs and drawings
- Historic structure reports (Preservation Brief 43)

Understanding Window Systems



Window Flashings and Sill Pans

Window Condition Surveys and Investigation Openings

- Partial or 100% survey – influences set up of CDs and bids
- Coordinate observations with repair specifications
- Investigation openings may reveal hidden conditions
  - Corrosion of steel frame embedded in masonry
  - Fiber optic borescope to survey additional windows

Window #	Type (A,B,C...)	Gen. Cond.			Window Element Repairs									General Notes	Photo #'s
		Ext. Paint	Int. Paint	Exterior Sealant	Exterior Sill	Exterior Frame	Int. Frame Pocket–R	Int. Frame Pocket–R Notes	Int. Frame Pocket–L	Int. Frame Pocket–L Notes	Sash (Lower)	Sash (Upper)	Operable (Y or N)		

Window Type:
A - Double hung 3-over-3
B - Triple hung 6-over-6-over-6
C - Quadruple hung fanlight-over-3-over-6-over-6

General Conditions:
Paint:
I - Mostly intact, minimal loose paint [minor sanding, repainting]
II - Minor cracking, peeling [10-50%, limited paint removal, some scraping, paint removal; repainting]
III - Major cracking, peeling [50-100%, significant paint removal; scraping, paint removal; repainting]

Ex. Sealant:
I - Mostly intact [seal minor gaps]
II - Minor deterioration [10-50%; seal holes, gaps]
III - Major deterioration [50-100%; replace sealant]

Window Element Repairs:
I - No Corrosion, peeling paint, dirty
II - Minor damage, isolated dime-sized corrosion
III - Major damage, rusted through areas greater than dime-sized, missing element(s)

Performance Criteria for Evaluating Windows

- Water penetration
- Air infiltration
- Energy performance
- Acoustics
- Blast resistance
- Repair or replacement costs
- Maintenance costs

Resistance to Water Penetration

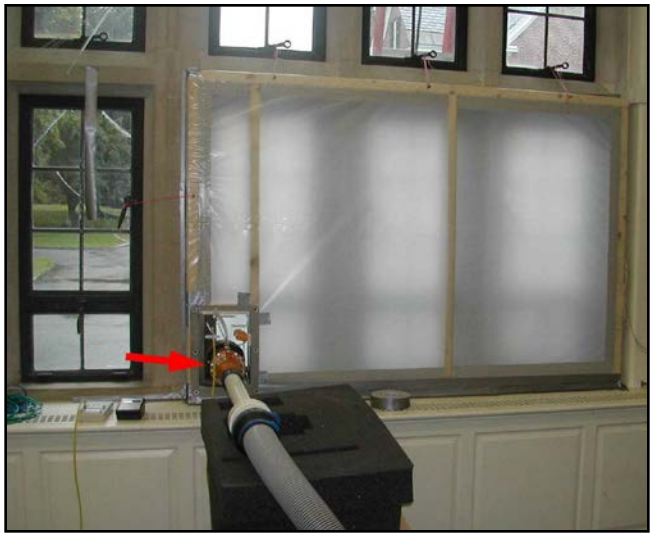
- *Windows should not leak under normal weather conditions*
- Spray rack w/differential pressure (ASTM E 1105)
- Selection of test pressure
  - NOAA weather records and AAMA 511 Procedure
  - Pressure based on wind speed while it is raining
  - Start testing at 0 psf; incremental pressure

Resistance to Water Penetration

- *Windows should not leak under normal weather conditions*
- Nozzle testing to isolate leak path
- Used to determine what to repair

Air Infiltration Testing
Types of Tests

- *Criteria depends on use of building and required energy performance*
- Quantitative testing
  - ASTM E783
  - For energy calculations
  - Differential pressure chamber
  - Flow measurement device
- Qualitative testing
  - ASTM E1186
  - Where air leaks occur and relative magnitude
  - Pressurization of rooms or whole building
  - Blower door test



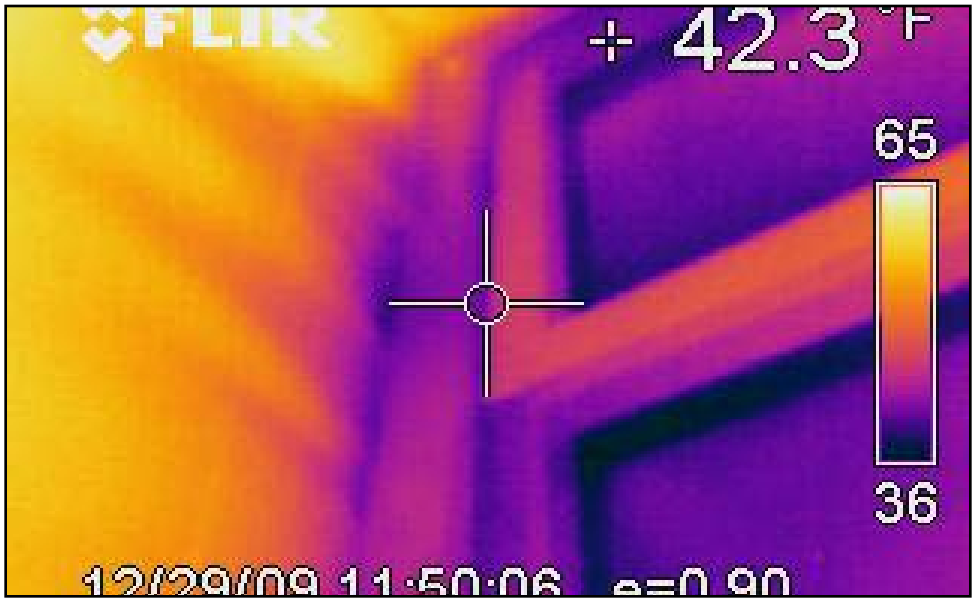
Differential Pressure Test Chamber

Blower Door Test

Air Infiltration Testing
Observing Air Infiltration

- Methods to observe air leakage
  - Tracer smoke
    - Visually observe from exterior
  - Infrared thermography
    - Requires temperature differential between interior and exterior

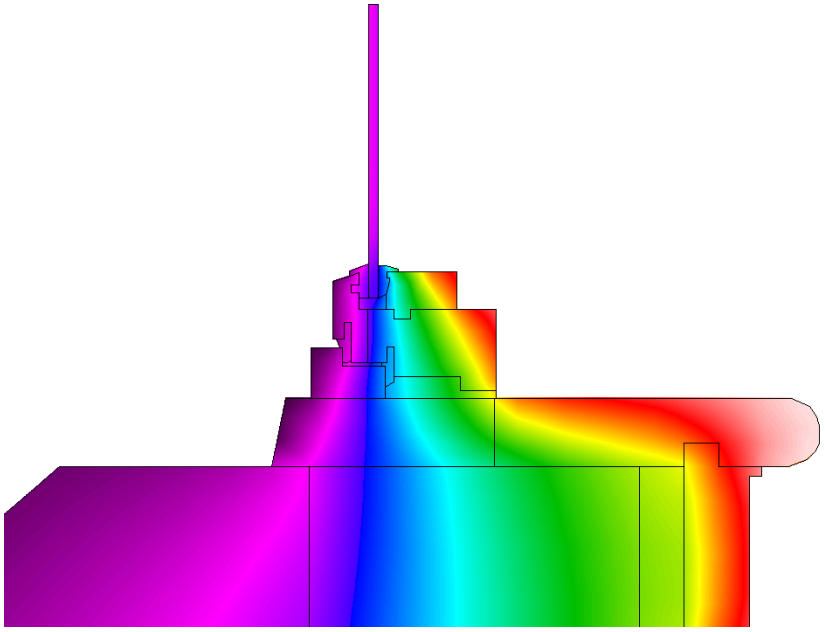
Tracer Smoke

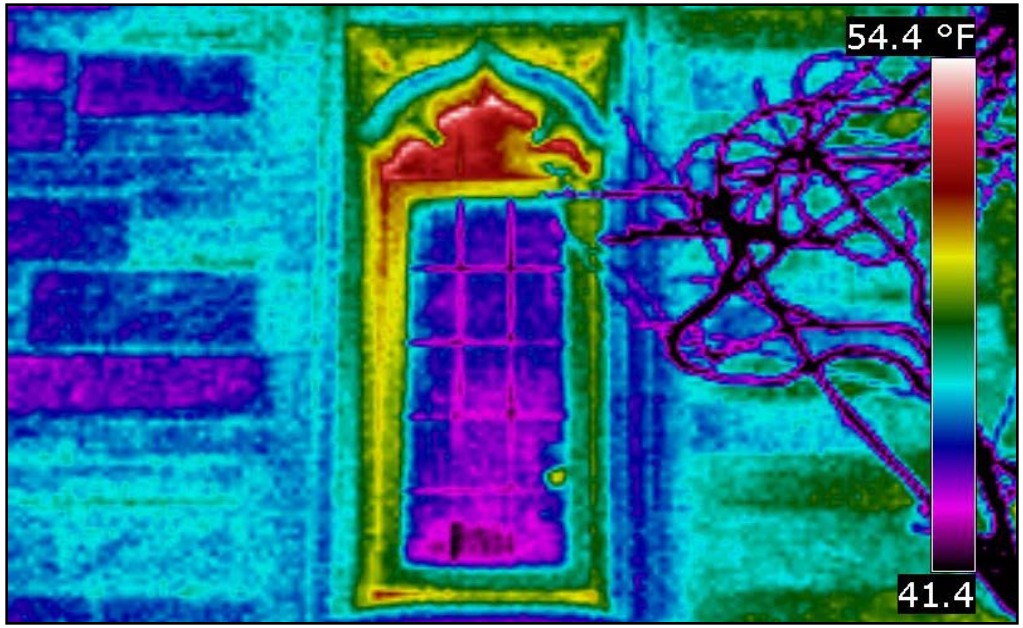


Infrared Thermography

Energy Performance
Window Assembly

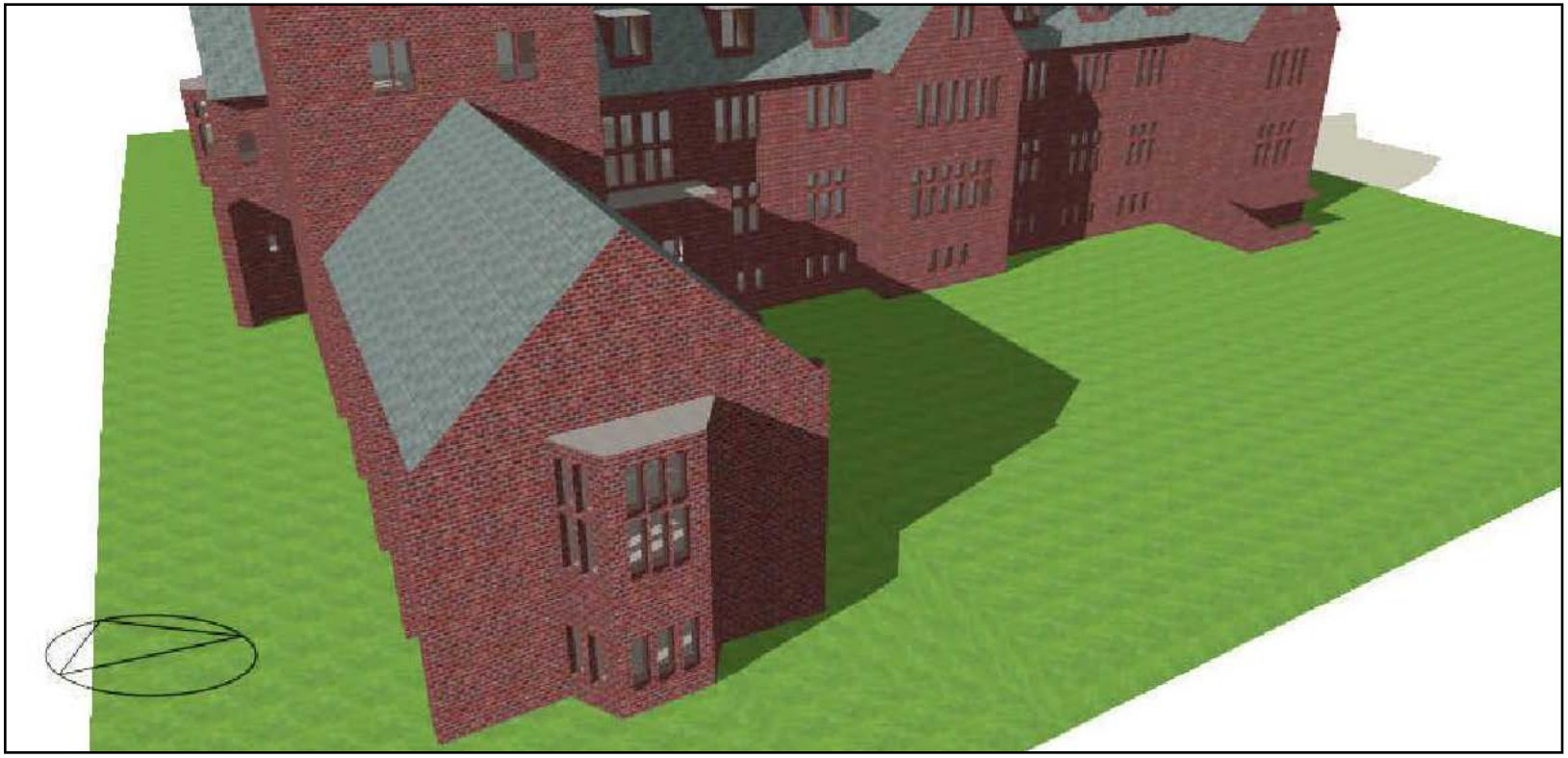
- Quantitative: air infiltration measurements + heat flow measurement
  - Air infiltration from quantitative testing
  - Computer simulation of heat flow of existing windows
- Qualitative: infrared thermography





Whole Building Energy Evaluation

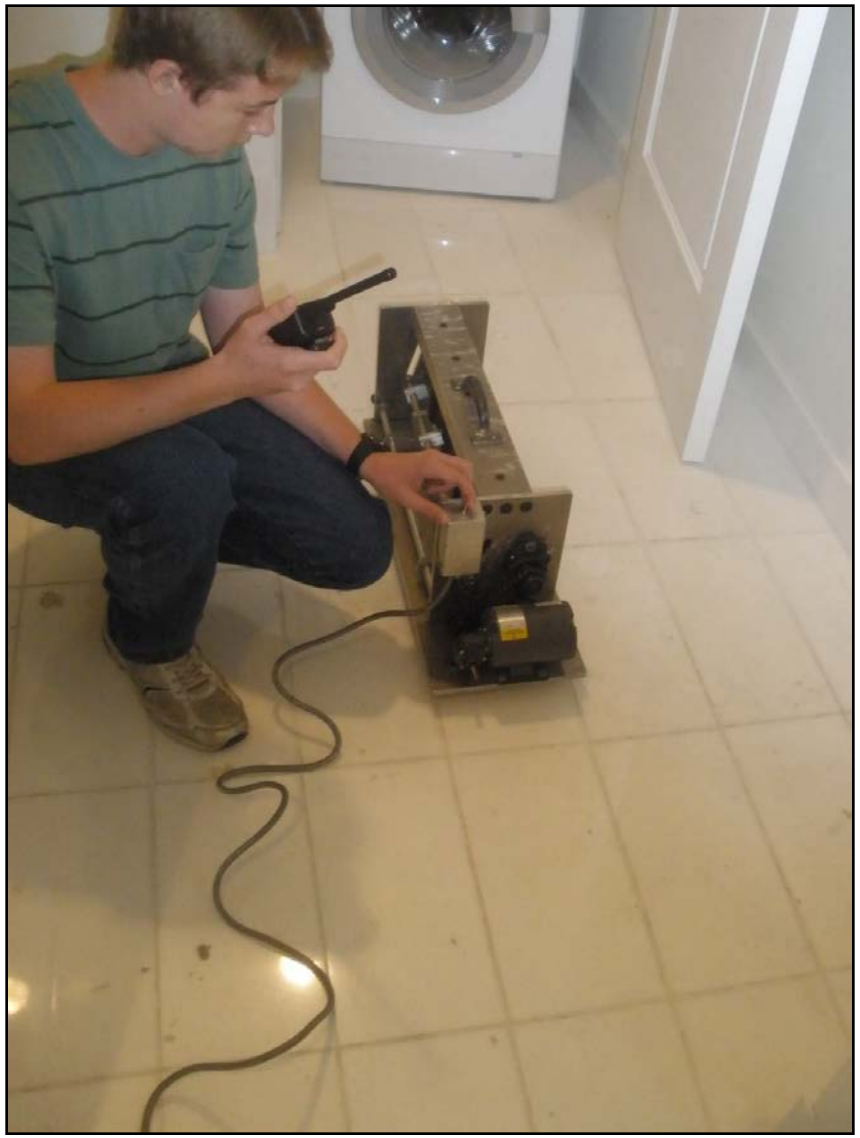
- Computer simulation considers internal loads, solar exposure/shading, occupant activities, time-varying interior and exterior conditions
- Include air leakage through and around windows (may be significant)
- Model various repair and replacement options for windows, roofs, walls



Energy model geometry of masonry building used to study benefits of window replacement

Acoustic Performance

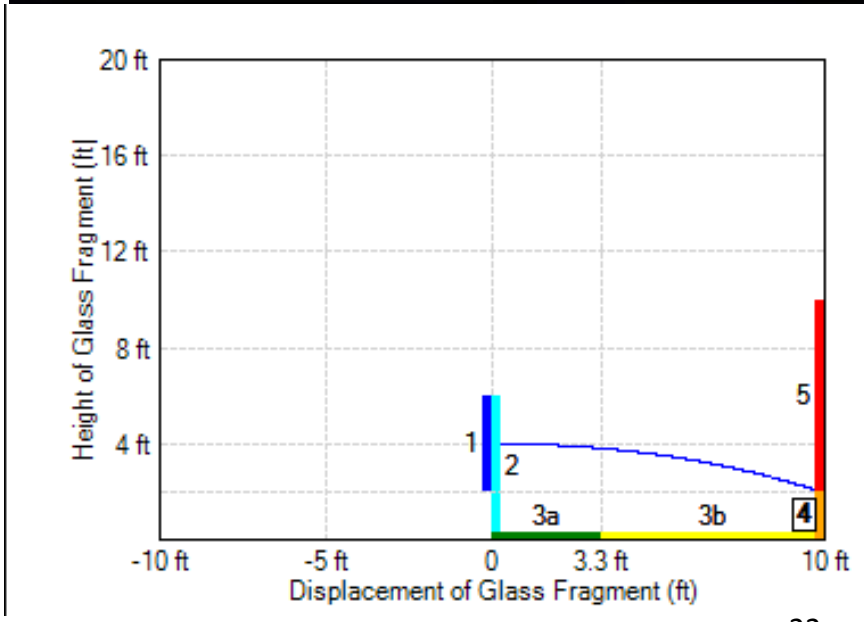
- *Allowable sound transmission dictated by building code or owner*
- Depends on building's use
- Measure on-site by acoustic engineer



Acoustic testing of flooring

Blast Resistance

- *Goals: provide walls with ability to resist large impulsive pressures without generating debris that penetrates the habitable space*
- Analysis
  - Weapon definition
  - Limit injuries due to fragments penetrating occupied space
  - Software
- Strategies
  - Exterior storm windows
  - Clear film on glass
  - Interior blast curtains
  - Site modifications



Repair and Maintenance Costs

Evaluate repair, replacement and maintenance costs

- Repair vs. replacement costs
- Expected lifespan of repaired and replacement windows
- Repair mockups to demonstrate effectiveness and estimate time to install repairs
- Life cycle cost analysis

Repair and Replacement Examples

- Repair material deterioration
- Repairs to address Air Infiltration and Water Penetration
- Upgrading energy performance
- Replacement in kind or with substitute materials

Repair/Replacement Options
Wood Window Repair in Place

- Retain existing windows
- Repair or replace deteriorated elements

Repair/Replacement Options
Wood Window Repair in Place

Repair/Replacement Options
Wood Window Repair in Place

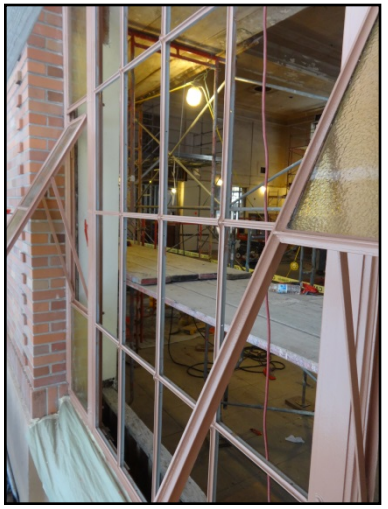
Repair/Replacement Options
Wood Window Repair in Place

Repair/Replacement Options – Repair in Place Steel Windows

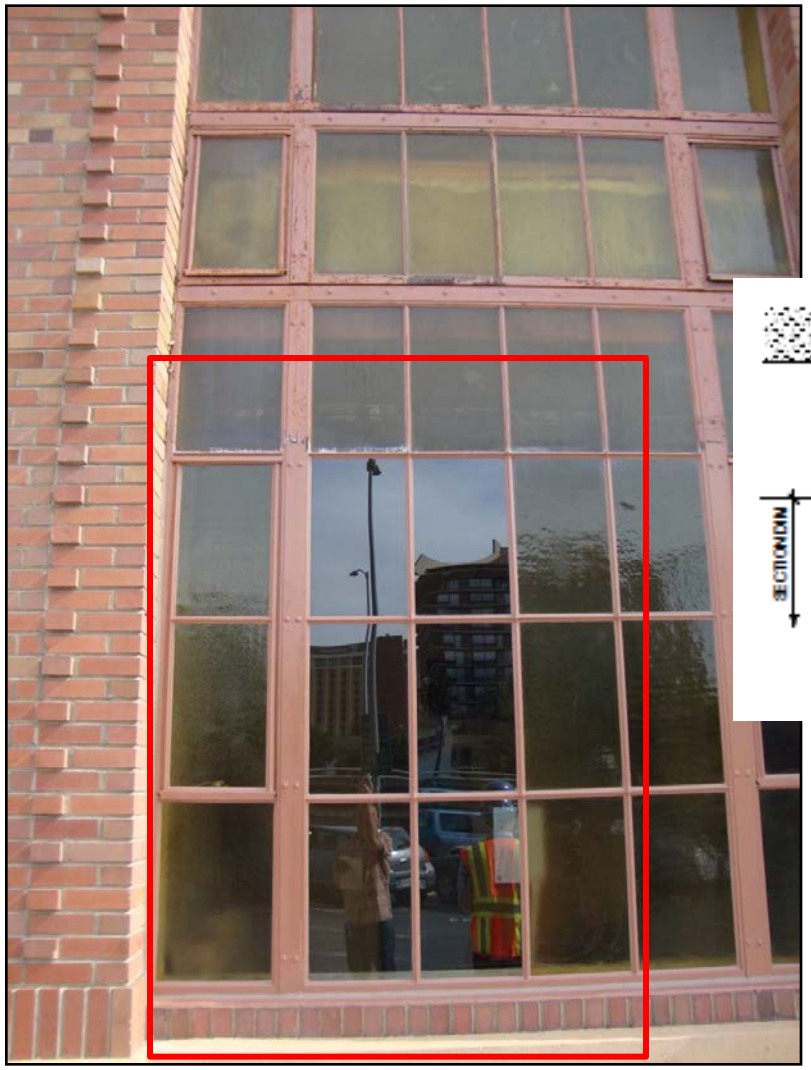
- Steel framed
- Paint peeling, frames rusting
- Cracked, missing, mismatched glass
- Window lintels rusting & deflecting

Repair/Replacement Options – Repair in Place Steel Windows

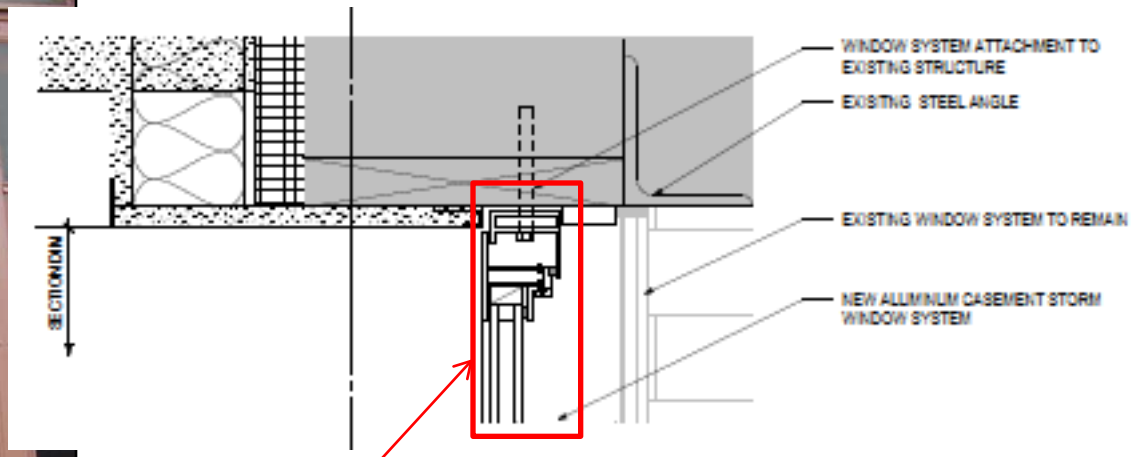
- Deglaze windows; save glass
- Paint entire steel frame
- Reglaze
- Seal window perimeters
- Paint or replace lintel angle



Repair/Replacement Options – Repair in Place Steel Windows w/Storm Window



Window repair mockup



Interior storm window

Repair/Replacement Options

- Repairs to address leakage
  - Weather stripping
  - New glazing putty or sealant
  - Installing flashings
  - Perimeter sealant
  - Fixing operable windows
- Mock-up repairs and re-test

Repair/Replacement Options

- Complete window replacement
  - In-kind or substitute materials (steel to alum.)
  - Maintain profiles

Repair/Replacement Options

- Complete window replacement
  - In-kind or substitute materials (wood to wood)
  - Maintain profiles

Repair/Replacement Options

- Upgrading energy performance
  - Storm windows
  - Shutters
  - Replacing glass only
  - Films

Repair or Replace Existing Windows?

- Preservation considerations?
- Can repaired windows meet the air, water, thermal, acoustic and blast criteria? How did they perform in the mock up testing?
- Results of energy evaluation? How important are the windows to the energy performance of the building? Can their energy performance be improved?
- What are costs of repair, replacement and ongoing maintenance?

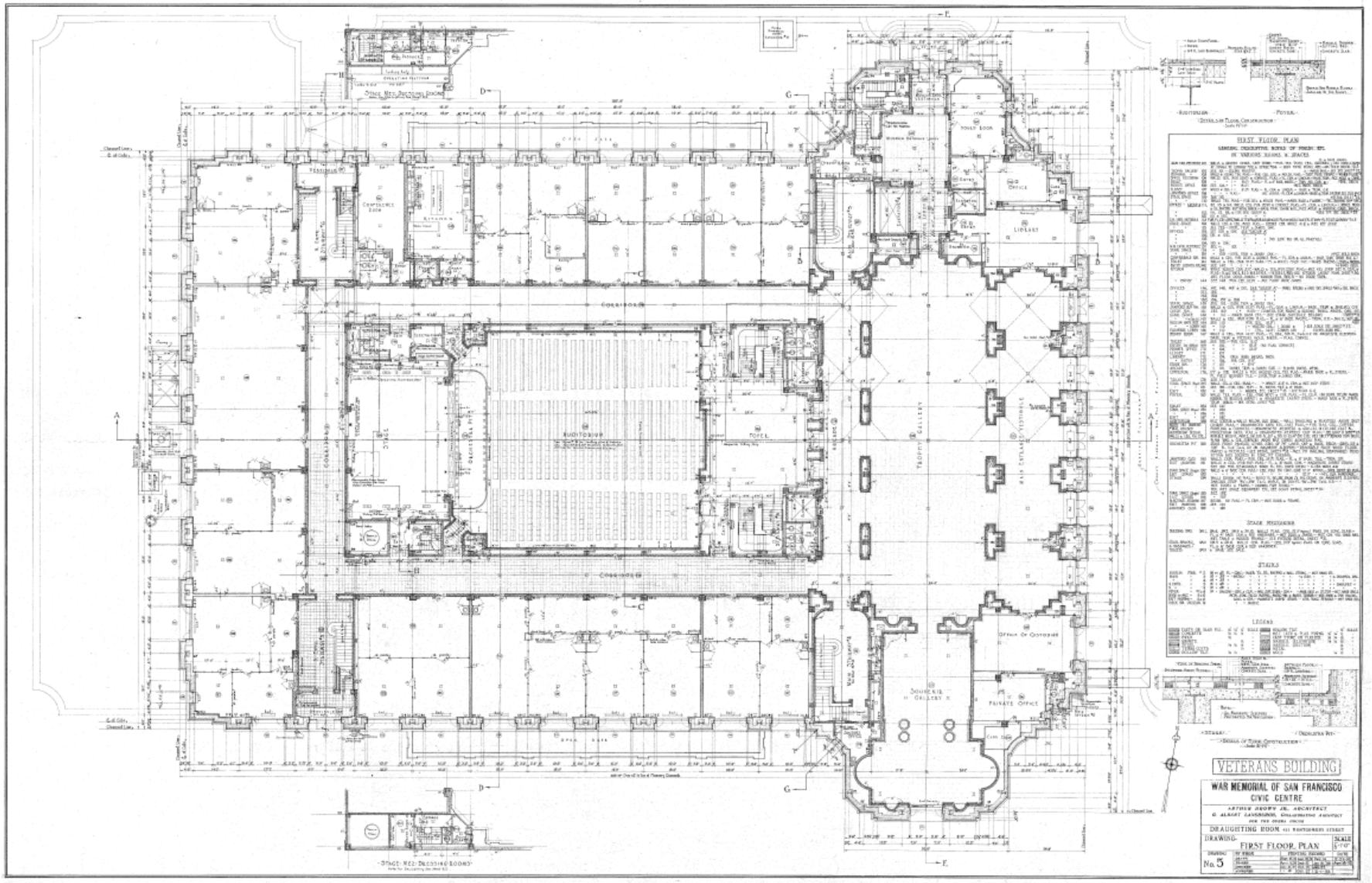
Case Study:

The War Memorial Veterans Building, San Francisco

The War Memorial Veterans Building

The War Memorial Veterans Building

Overall floor plan



Investigation Phase
(Fall 2011)

Steel windows

Steel windows

Steel windows

Small balconies at 2nd floor

Steel windows

Steel windows

Steel windows

Steel windows

Steel windows

Window Repairs (recommended)

- Rehabilitate windows: goal is to restore operability
  - Remove all glass (clean and reinstall where possible; replace where required due to cracks or non-matching)
  - Remove all paint from frames (test & abate hazardous paint)
  - Clean corrosion from frames; repair areas with section loss
  - Install original and new glass with new glazing putty
  - Repaint frames with rust-inhibiting primer and paint
  - Remove and reinstall exterior perimeter sealant joints
  - Replace broken or missing hardware

Design Phase
(2012)

Window Repairs (design scope)

- Rehabilitate windows: goal is still to restore operability
  - Retain all glass (replace only where required due to cracks or change in programming)
  - Remove all paint from frames (test & abate hazardous paint)*
  - Clean corrosion from frames; repair areas with section loss
  - Wet seal all existing glass
  - Install new glass with new glazing putty
  - Repaint frames with rust-inhibiting primer and paint
  - Remove and reinstall exterior perimeter sealant joints
  - Replace broken or missing hardware

Window Repairs: glazing putty vs. wet seal

Glazing putty repair

Wet sealant repair

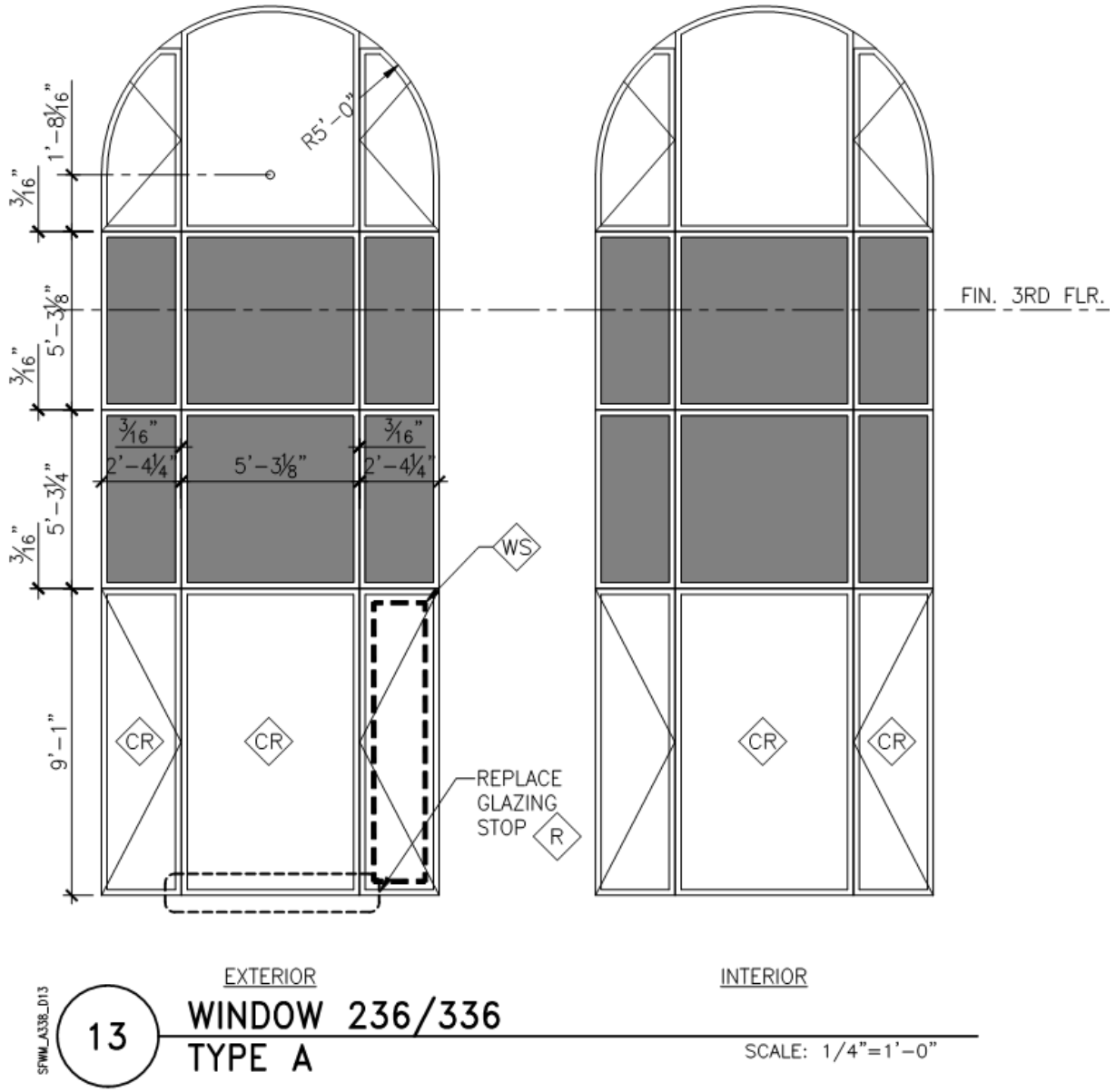
Specifications: performance requirements?

- Water test windows
- But, what performance level?
  - Need to understand current performance…
- Recommended mock-up testing during design
  - Understand current performance, and performance of recommended repairs
  - Do 2 mock-ups:
    - SGH recommended scope (remove & replace all glass with new glazing putty)
    - City desired scope (wet seal windows)

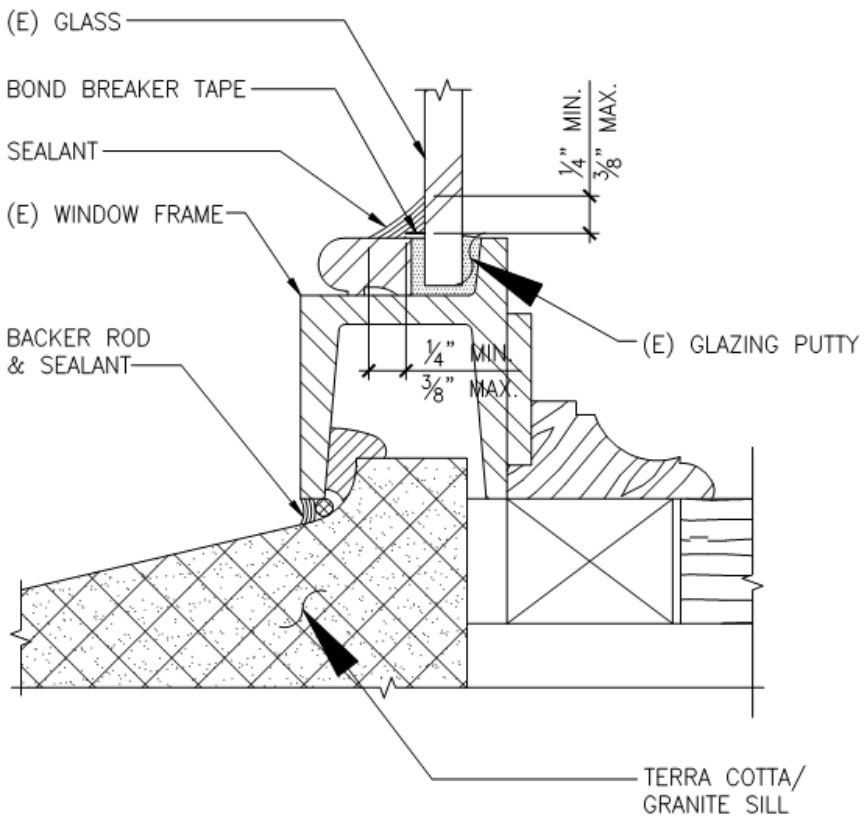
Window Repairs (design scope)

- Construction documents:
  - Elevation of each window showing anticipated repairs
  - Allowances and unit pricing for glass and hardware repairs, steel frame repairs
  - Testing:
    - Mock-up prior to window repairs
    - Test 10% of windows (13 total) during construction
    - ASTM E 1105 at 3 differential pressure levels: 0, 1.5 psf, 3 psf

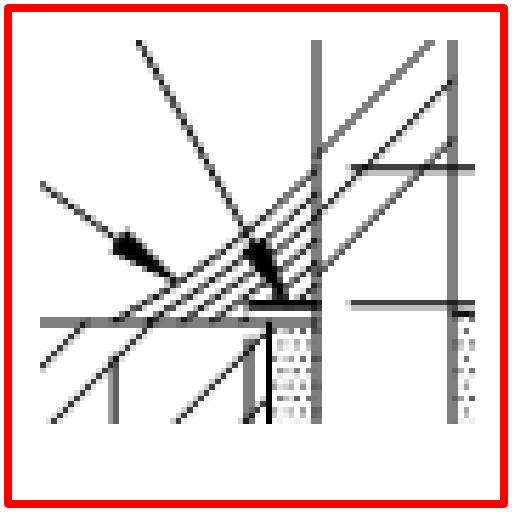
Window Repairs (design scope)



Window Repairs (design scope)



NOTE:
FOR REPLACEMENT GLAZING
INSTALL NEW GLAZING PUTTY.



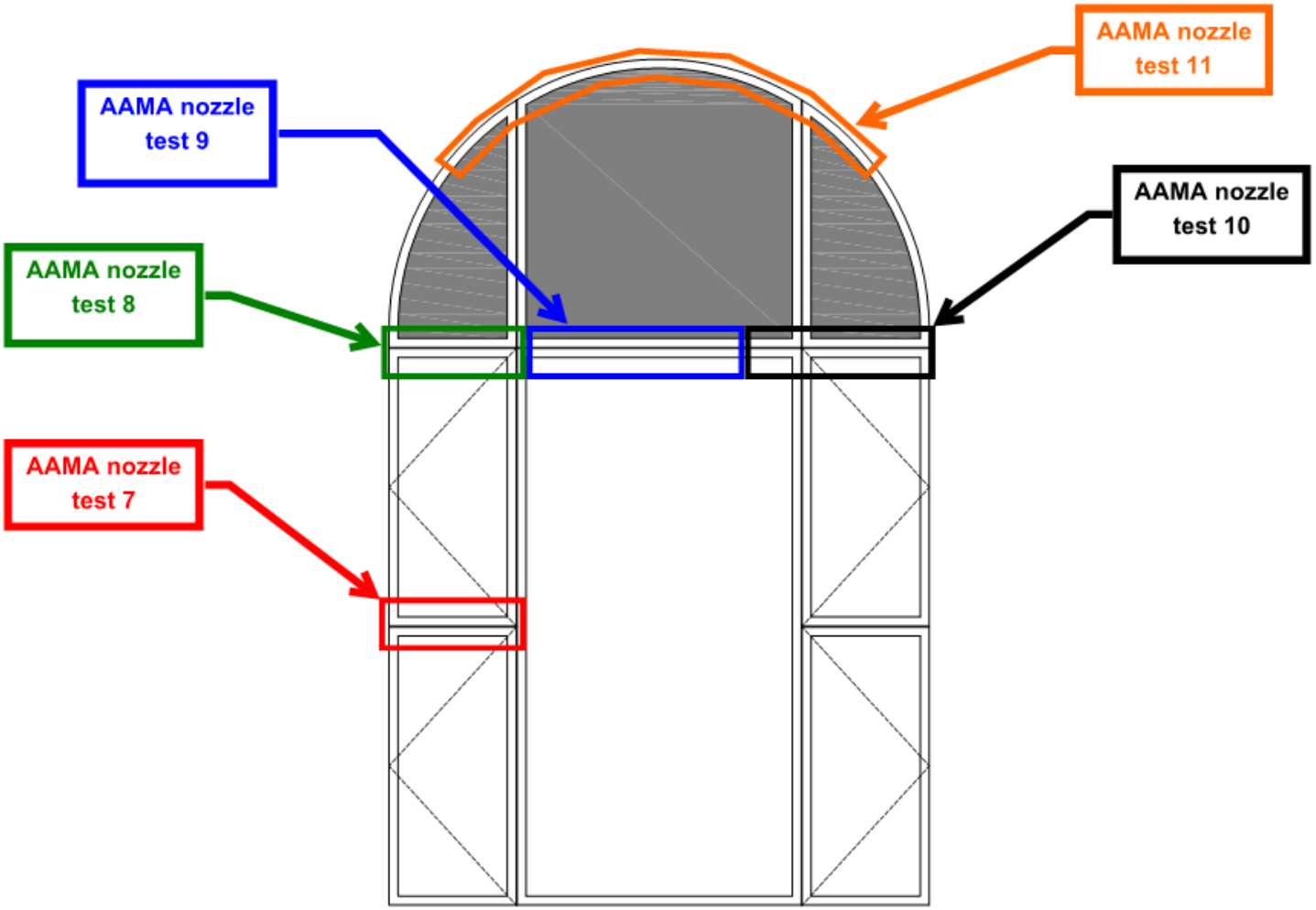
SFWM_A906_004

4 TYPICAL WET SEALING AT GLAZING & PERIMETER SEALANT AT SILL SCALE: FULL SCALE

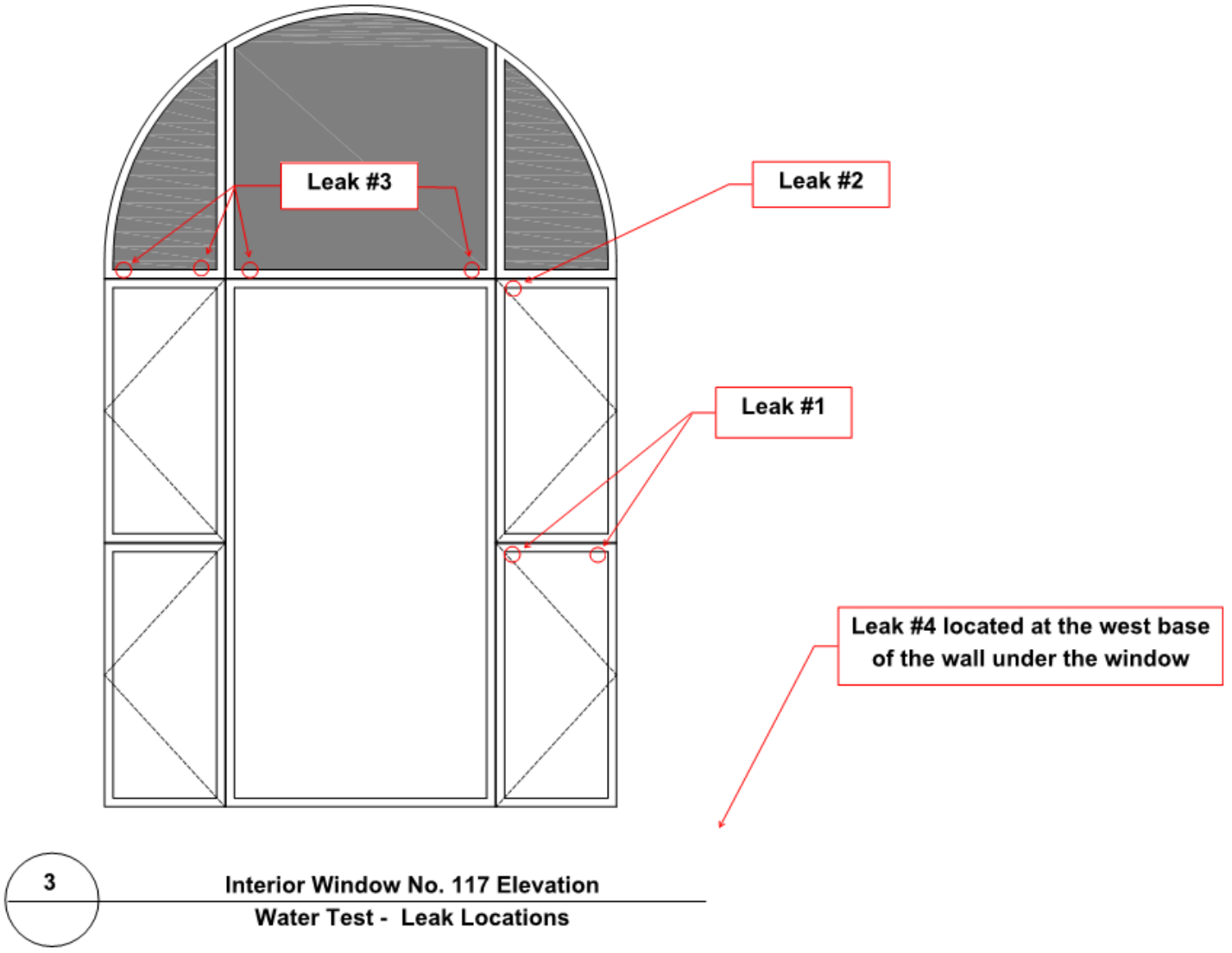
Construction Phase
(2013-2015)

Mockup Window Testing

Mockup Window Testing



Mockup Window Testing



Mockup Window Testing

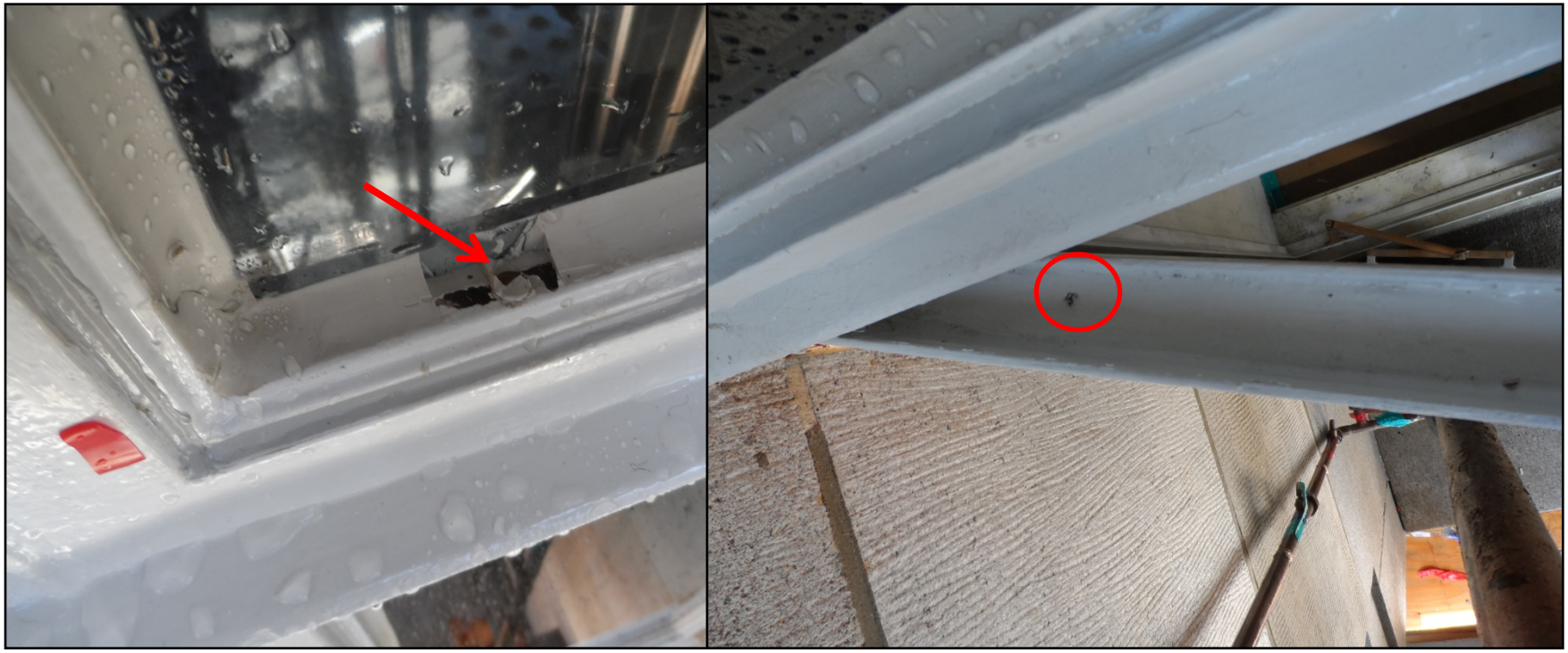
- Leak 1: debonded wet seal
  - Repair: remove and reinstall without bond breaker tape.

Mockup Window Testing

- Leak 2: debonded wet seal at location of existing paint on frame
  - Repair: completely remove existing paint from frames.

Mockup Window Testing

- Leak 3: at screws in glazing stop to window frame
  - Repair: bed new screws in sealant; dome sealant over top of all screws after wet sealing



Mockup Window Testing

- Leak 4: at unpointed mortar joint in granite
  - Repair: repoint all joints in granite (and terra cotta) adjacent to windows

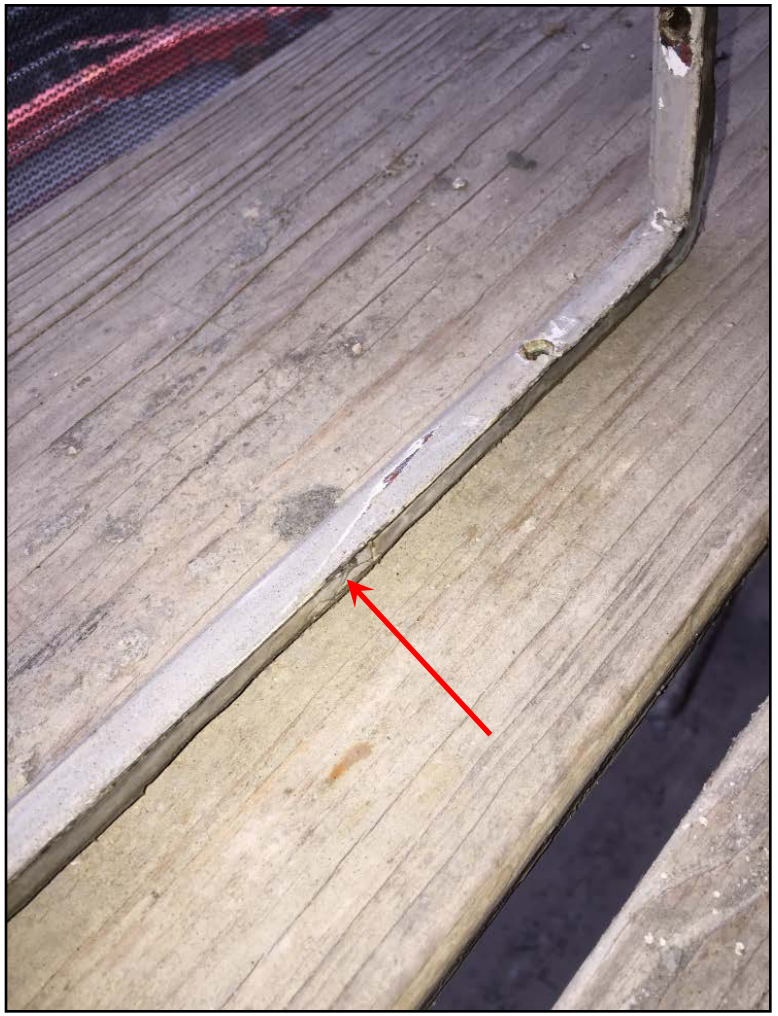
Window Testing During Construction

- Water entry: different from a leak; not a failure
  - Two drops at 0.58 in. differential pressure (3.0 psf)

Additional Glazing Stop Repairs

- Found extensive bowing, causing glass to crack; broken screws
- Required removal to clean corrosion, reshape
- Primed back side (in contact with glass)
- New screws
- Only occasionally was replacement required
- Major cost impact to project

Mysterious Cracking During Construction



Water testing windows during construction

- Leaks through frame

Testing windows during construction

- Leaks through balcony (under window frame)

Testing windows during construction

- Leaks through hardware

Lessons Learned

- Performing a mockup of intended repairs (or multiple repair scopes) during design can provide significant value: confirm required scope, performance and cost expectations
- 100% survey of interiors not enough to understand the condition of the exteriors
- Trade-offs between correct sealant joint design and limitations of existing conditions
- Old glazing putty does not perform well
- Mock-up testing is most valuable before window repairs proceed
- When testing windows, make sure repairs at surrounding construction are complete

Thank You

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